Research Paper | Engineering | E-ISSN No : 2454-9916 | Volume : 10 | Issue : 8 | August 2024

HYDROLOGICAL IMPACT OF LAND USE AND LAND COVER CHANGE IN THE UPPER GODAVARI BASIN, MAHARASHTRA, INDIA

J. C. Patil[1], S. T. Wanjari[2], H. S. Chaudhari[3], A. C. Kalel[4], V. R. Saraf[5]

[1,2,3,4,] Government College of Engineering, Jalgaon, India

[5] Assistant Professor, Government College of Engineering, Jalgaon, India

ABSTRACT

This study examines how changes in land use in the Upper Godavari River Basin of India affect hydrology. The ArcView Interface of Soil and Water Assessment Tool (AVSWAT2000) was utilized to figure out the alteration in land use. With the LANDSAT data that was accessible in ArcMap, landcover maps for the years 2003, 2013, and 2023 were created. The WRIS portal, sourcing ground water level data for 2003, 2013, and 2023 as well as the river point data for 2003 to 2013 by CADA, Chhatrapati Sambhaji Nagar formed the linking components. According to the study, there was a discernible growth in the areas of other basin components during these three decades, whereas there was a notable decline in the scrubland area (89.59%). In addition, a decrease in ground water levels was observed along with an increase in river discharge. Increased urbanization in the river basin was the main factor causing discharge to rise and ground water levels to fall at the sub-basinal scale. According to these findings, the SWAT model seemed to be a helpful tool for identifying LULC changes so that the relationship between LULC, river discharge, and ground water levels may be better understood.

KEYWORDS: Landuse Change, AVSWAT2000, Ground Water Level, Discharge, River Basin

1. INTRODUCTION

The management of water resources necessitates a systems approach that considers not only all the hydrological components but also their relationships, interactions, linkages, and repercussions. These days, human-caused environmental changes, such as altered land cover, irrigation, and flow control, happen on a scale that greatly influences annual and seasonal hydrologic fluctuations *(Dadhwal et al., 2010)*. Thus, for effective management of water resources, it becomes essential to comprehend and quantify the many hydrological components of the catchment.

Therefore, knowledge of the many hydrologic components of the catchment becomes crucial for effective management of water resources. The landcover and soil type cover are two of the catchment's many features that should be studied to understand different hydrological changes. A catchment's land use is one of the primary determinants of its watershed hydrology and discharge *(Sinha et al., 2015) (Roy et al., 2010)*.

Because river basins enable a comprehensive knowledge of upstream and downstream hydrological interactions and its solution for management for all the competing sectors of water demand, they are recognized as the ideal and practicable measure of water resources management. Therefore, it is crucial to comprehend fundamental features unique to a given river basin.

The Godavari River elevates 1,067 meters above MSL in the Sahyadri's (Western Ghats), close to the Trimbakeshwar in the Maharashtra district of Nashik. Significant watershed and hydrological functions are carried out by the Western Ghats. The Indian states on the peninsula, inhabited by over 245 million people, rely mostly on waterways that originate in the Western Ghats for their water supply. People relying on this region's soil and water, to support their way of life, accounts to over a Million in number. No other biodiversity hotspot has such an influence on the lives of such an enormous population, possibly except for the Indo-Malayan region.

In the current study, Soil and Water Assessment Tool (SWAT) has been used to detect the land use changes in the upper Godavari basin for 3 decades i.e. of the years- 2003, 2013, 2023. This is done for comprehending the distribution of the physical characteristics over the catchment and the changes occurring in it over the time. This can be done by spatial data analysis integrated with remote sensing and image processing, efficiently using the GIS tools *(Dadhwal et al., 2010)*. Comparative studies of land use detection are critical for informing policy decisions, guiding urban planning efforts, and encouraging sustainable land use practices.

Changes occurring in a regions land use and land cover may modify its various characteristics in many ways like, increase surface runoff and erosion (Urbanization & deforestation) leading to higher sediment loads in watershed; increased nutrient and pesticide runoff (changes in agricultural activities) affecting the water quality; alteration in the natural flow patterns of rivers and streams within the watershed; Increased impervious surfaces in urban areas can lead to faster and more variable streamflow, while deforestation can reduce streamflow and alter the timing of water inputs to the watershed; fragmentation of wildlife habitats and affect in the connectivity of ecological systems within the watershed (conversion of natural habitat to

agricultural or urban land); impact on the diversity of plant and animal species within the watershed, in addition to offering ecological services like water filtration, flood regulation, along with carbon sequestration.

The purpose of this study was to quantify the effects of prior LULC modifications on discharge in the Upper Godavari basin, providing information for water resource management and sustainable development.

2. STUDY AREA

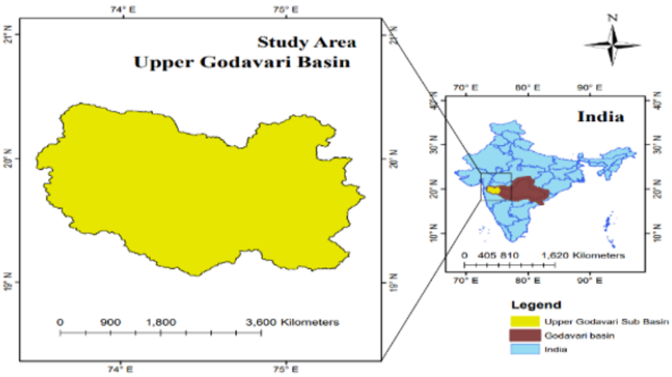
A river basin, at its proper scale, is typically the most sensible geographic division for discharge analysis and water resource management.

The Godavari River being the second longest river in India, spans up to 1465 kilometres and makes up to over 10% of the country's total land area. It originates in the Western Ghats in central India, close to Nashik in Maharashtra (1067 m. height). The Ganga River comes before it.

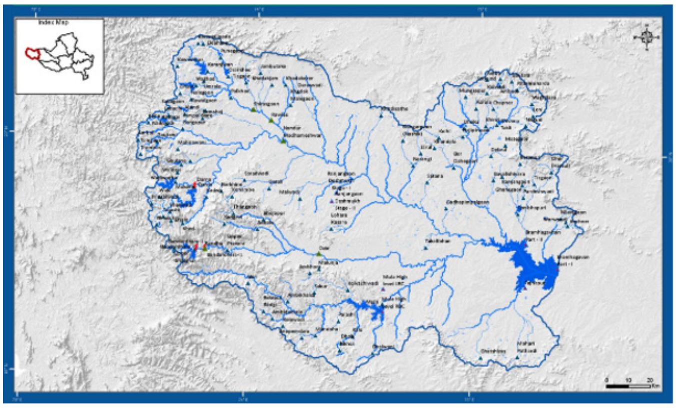
A considerable part of the Godavari River basin lies in Maharashtra (49%) followed by Andhra Pradesh (24%), Chhattisgarh (12%), Madhya Pradesh (8%), Odisha (6%), Karnataka (1%) and the least in Puducherry before draining into the Bay of Bengal, forming a delta. This basin is the third largest in the Indian subcontinent, where most of the population is dependent on agriculture. A major part of the basin's rainfall is obtained throughout the south-west monsoon season. The study area, Upper Godavari sub-basin of the Godavari River, lies between 19°06′0″ N & 20°45′ N, and 73°5′ E & 75°38′E, latitudes, and longitudes, respectively. The total size of the study region (watershed) is 22223.268415 Km^2 (2222326.8415 hectares).

The river in the sub-basin starts flowing from its origin in trimbakeshwar before getting into the Gangapur dam joined by the Darna River. The major rivers in the sub-basin include Pravara, Mula, and Shivana all draining into the catchment of the Jayakwadi Dam, as one of the major projects in the basin. The drainage network's uniform lithology and inadequate structural management lead to a good dendritic structure. The rivers are ranked nearly all the way to their source; however, this ranking is not based on sea level but rather on the crystalline girdle encircling the basaltic plateau; the prior, being significantly more resilient, controls the base level virtually.

The major CWC sites in the sub-basin include the Kopergaon Flood Forecasting Station and the Pachegaon gauge, discharge station.



a. Study Area



b. River network *(Source: WRIS)*

Fig 1. Study area (Upper-Godavari basin)

Because the basin is somewhat large, climate contrasts, notably fluctuations in rainfall, are noticeable. Temperature conditions do not alter greatly due to a limited latitudinal breadth and a very small vertical range of altitude. Climate has played a significant effect on landscape evolution. The Godavari basin's climate is tropical, and experiences significant losses due to evaporation in several areas of the basin. The weather in the basin is chilly from mid-October to mid-February, with the western and north-eastern portions being much frigid than the remainder of the basin. The westernmost areas of the basin get hotter weather than the central, northern, and eastern regions *(Source: WRIS, Godavari Basin)*. Loam, Clayey loam, and Sandy Clayey Loam-textured soils can be found outspread in the sub-basin.

3. METHODOLOGY

The graphical user interface (GUI) for the SWAT (Soil and Water Assessment Tool) model is provided by the ArcSWAT ArcGIS plugin *(Arnold et al., 1998)*. The tool is developed to forecast the effects of land management methods on water, sediment, and agricultural chemical yields in large, complex watersheds with shifting soils, land use, and management conditions over extended periods, SWAT is a river basin, or watershed, scale model. The model allows users to examine long-term effects and is physically grounded and computationally efficient. It also makes use of easily accessible inputs. Numerous investigations involving the modelling of watersheds and water quality can be supported by the SWAT model.

A system of several hydrologically related watersheds or a single watershed can be simulated using SWAT. Based on the distribution of soil types and land uses, every watershed is foremost split into subbasins and subsequently into hydrologic response units (HRUs). The HRUs have same hydrological & geomorphologic characteristics and are homogenous spatial units. The current study solely focuses on the land use detection of the area of interest and defining the HRUs, based on soil and land use distribution.

The entire process of Watershed Delineation is divided into five sections- DEM Setup, Stream Definition, Outlet and Inlet Definition, Watershed Outlets(s) Selection and Definition, and Calculation of Subbasin Parameters *(Source: SWAT User Manual)*.

The DEM (Digital Elevation Model), serving as a major input was prepared by downloading 1 Arc-second data (30m) resolution data in the form of tiff files from the USGS Earth Explorer. The DEM was then corrected for sinks for generating a fill grid map in the ArcMap Software. Latterly, a Flow direction and Fow accumulation map was derived from the fill sink map, respectively. For the Stream definition, derived from the flow accumulation, maximum threshold area (10000 hectares) was specified for delineating the drainages. Extraction of a subbasin for each delineated stream was then done and afterwards, 3 outlets at Jayakwadi Dam was defined. A river network and basin for the defined outlet was delineated. It was further divided into various number of subbasins (139 subbasins) with outlets with existing gauge stations along the extracted drainage. The extracted network was then overlaid with other thematic layers of land use and soil type, and thus definition of distribution of various parameters and properties in the basin was done.

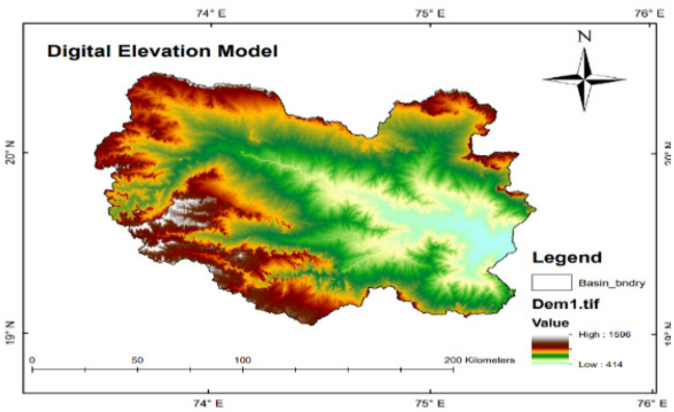
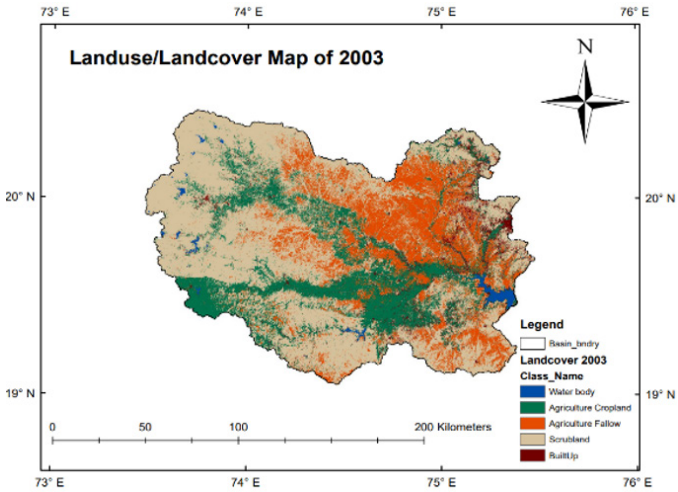


Fig 2. Digital Elevation Model

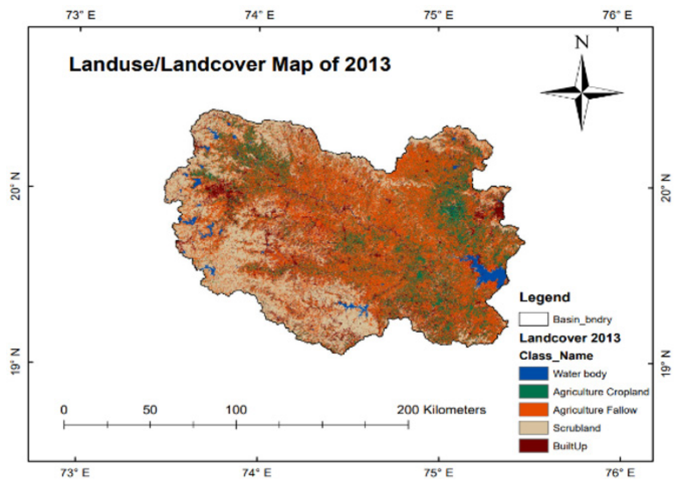
Images obtained by remote sensing show portions of the earth's surface as viewed from orbit *(Anil et al., 2010) (Kamal et al., 2012)*. These images being reliable and providing general views of large areas were the possible option to study the landcover dynamics on a regional scale *(Sharma et al., 1984) (Gautam et al., 2016)*. LANDSAT 4-5 MSS TM images (30m spatial resolution) of the year 2003 were downloaded from the USGS EE web-portal instead of LANDSAT 7 images due to the SLC error causing 50% data loss *(Rawat et al., 2013)*. The preprocessing and mosaicking were done in ERDAS imagine software to create a seamless image of the basin. The mosaiced image was then clipped to the subbasin boundary shapefile. The images were classified using supervised classification into 5 classes- Waterbody, Agriculture Cropland, Agriculture Fallow, Scrubland and Built-up; with the use of signature editor tools in ERDAS imagine.

Mapping of 2013 and 2023 was done using LANDSAT 8-9 OLI/TIRS images with 30m spatial resolution. The same process of preprocessing, mosaicking, and clipping to subbasin shapefile was followed to perform the task. The landuse/landcover maps of 2003, 2013 and 2023 for the upper Godavari basin are displayed in Fig.3 (a) (b) (c) respectively.

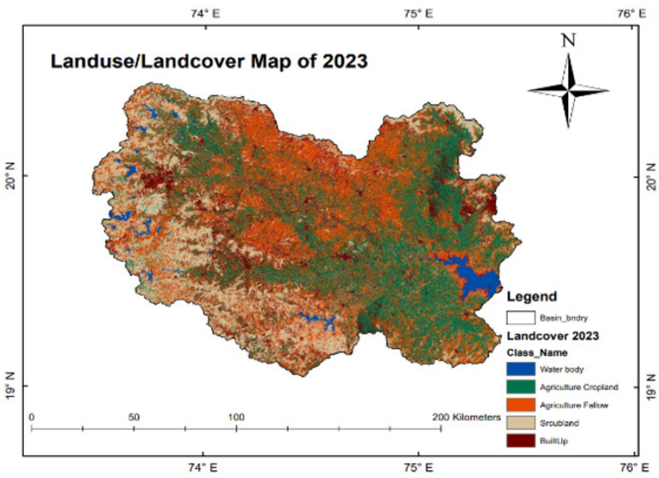
The SWAT landcover classes were defined manually instead of uploading a lookup table. The SWAT landcover/plant codes were defined by selecting the crop database for waterbody, agriculture cropland, agriculture fallow and scrubland and the urban database for built up. Each code must be assigned manually, one at a time for every year's landuse grid.



a. Landuse/Landcover Map of 2003



b. Landuse/Landcover Map of 2013



c. Landuse/Landcover Map of 2023

Fig.3 Landuse/Landcover Map of 2003,13&23

To limn the spatial distribution of each soil, soil mapping involves locating and categorizing the many types of soils that exist, gathering data on their characteristics, textures, potential uses, and recording this data on maps and supporting documentation.

The soil data i.e. the world soil map was downloaded from the FAO portal at a scale of 1:5000000 resolution. The map was then projected, clipped in the study area shapefile, and converted from vector to raster in ArcMap. The value field was set to SNUM, and the local meaning of the soils were found in the user soils table in the SWAT 2012 database *(Shimelis et al., 2008)*. The SNUM numbers were the same as found in the SEQN column of the user soils table. Various soil properties and textures can be found in the table. The local soil names were then given, and a Digital Soil Map (DSM) was prepared to be overlaid upon the DEM and LULC layers as shown in Fig.4

Like the LULC, the soil attribute data was assigned manually for the soil grid.

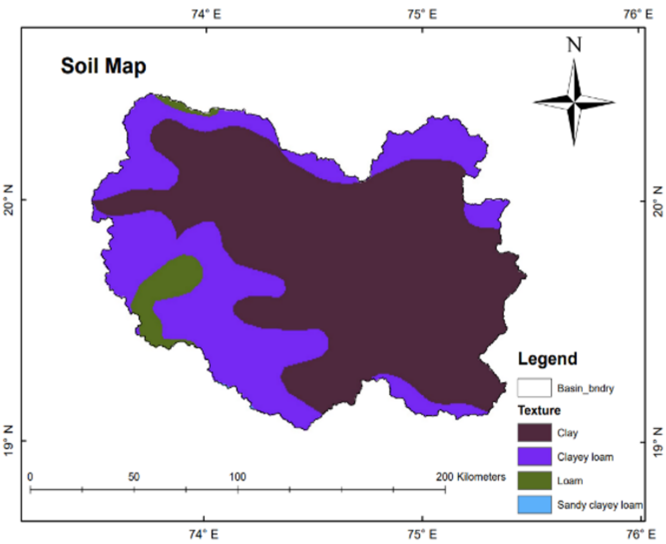


Fig.4 Soil Map

In ArcSWAT, the HRU analysis includes division by its slope classes moreover, the landuse and soils. This is a necessity when these subbasins have a wide range of slopes within them, but not in this case. A single slope class was desired for the HRU delineation and reclassified after the LULC and soil grid overlay.

For HRU definition, multiple HRUs were selected per subwatershed and 5% value was defined for each landuse, soil and slope threshold levels. The HRU distribution was then determined.

4. RESULTS AND DISCUSSIONS

A comparison of the land use change over the decades- 2003, 2013 and 2023 revealed some noteworthy changes in the Upper Godavari Basin. The landcover changes are then linked to the discharge data, for the years 2003 to 2013 *(Source: CADA, Chhatrapati Sambhaji Nagar)*. Groundwater level data *(Source: WRIS, CGWB)* of the years 2003, 2013 and 2023 have also been used for the assessment of hydrological activity in the basin.

The dominant LULC type of the Upper Godavari River basin has changed from Scrubland to Fallow land over the decades. The Scrubland accounted for 55.69% of the entire area for 2003 and significant decrease has been attributed to it resulting in 28.68% and 21.23% for the years 2013 and 2023 respectively. Agriculture and urban area increased, however no major changes occurred in the water body of the basin, which may be driven by a variety of causes *(Rawat et al., 2015)*.

The LULC of the Upper Godavari River Basin changed from 2003 to 2013 significantly. The fraction of urban area increased from 3.04% to 9.58%, fallow land decreased from 20.57% to 45.51%, scrubland decreased from 55.69% to 28.69%, and cropland decreased from 20.35% to 15.27%. The percentage of the basin's water body rises from 0.35% to 0.95% in this decade.

In the Upper Godavari River Basin, the percentage of agriculture increased from 15.27% to 29.38% between 2013 and 2023, while the proportionate extend of urban area increased from 9.58% to 12.46%. Fallow land decreased from 45.51% to 35.60%, and scrubland decreased from 28.69% to 21.23%. The percentage of the basin's water body rises from 0.95% to 1.33% between 2013 and 2023.

This suggests that during a 30-year period, the total amount of scrubland has decreased at the price of an expansion in the basin's built-up area, agricultural cropland, fallow land, and water body. The dominating feature of the Upper Godavari River Basin changed from Scrubland to being an Agriculture land.

	Waterbody (%)	Agriculture Cropland (%)	Agriculture Fallow (%)	Scrubland (%)	BuiltUp (%)
2003	0.35	20.35	20.57	55.69	3.04
2013	0.95	15.27	45.51	28.69	9.58
2023	1.33	29.38	35.60	21.23	12.46

Table 1. LULC statistics of 2003, 2013 & 2023.

LULC type	2003 (Km2)	Study area. (%)	2013 (Km^2)	Study area. (%)	2023 (Km2)	Study area. (%)	Amount of chang (Km^2)	Percentage growth
Waterbody	78.69	0.35	210.76	0.95	294.21	1.33	215.52	115.59
Agriculture Cropland	4521.91	20.35	3393.55	15.27	6529.26	29.38	2007.35	36.33
Agriculture Fallow	4570.82	20.57	10112.93	45.51	7911.73	35.60	3340.91	53.53
Scrubland	12377.15	55.69	6376.12	28.69	4718.69	21.23	-7658.46	-89.59
BuiltUp	674.68	3.04	2129.89	9.58	2769.36	12.46	2094.68	121.64
Total	22223.25	100		100		100		

Table 2. Area (Km2) and overall amount of change (%) of study area over the decades.

In addition to the above changes, a decrease in the level of ground water has also been detected. The average ground water level was observed to be 8.59m in the year 2003 which decreased upto 7.01m and then 6.69m in the years 2013 & 2023 respectively. This decreases over the years, explain the cause of increased waterbody area in the basin due to less soil infiltration caused due to an increase in the builtup area *(Amin et al., 2012)*.

A comparison of river discharge data for the 2003-2013 decade has also been done and fluctuations have been seen in the river discharge. Due to less soil infiltration, increase in surface runoff is predictable, causing an increase in the discharge (for the year 2003 & 2013) *(Golaleh et al., 2010)*. The discharge that was 2.94M cum./day (34.02cumecs) in the year 2003, spiked to s3.59M cum./day (41.55cumecs) in the year 2013 with various noticeable fluctuations in the years between.

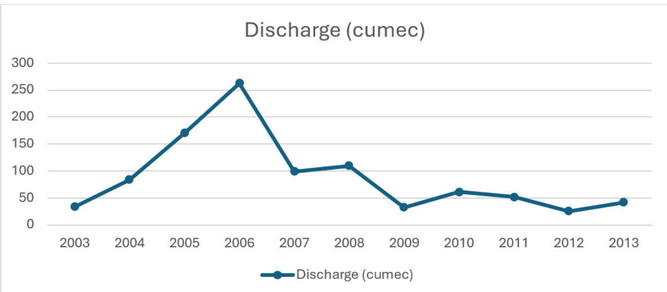


Fig.5 Observed yearly discharge of the Upper Godavari River Basin.

These results compared with the LULC change over the time showed that the impact of change in landuse in the Upper Godavari River basin increased the discharge while caused a decrease in the ground water level. Also, the landuse pattern in the study area was identified as most of the area is agriculturally dominant with an increase in the builtup land simultaneously, but at a slower pace.

5. CONCLUSIONS

One of the major observable changes that are occurring in our surroundings are the changes in land usage and land cover. Although noticeable, its size, variety and spatial unpredictability has made the quantification, along with the assessment of land use and land cover changes a challenging task.

The following changes are revealed by a thorough landcover mapping of the basin for the years 2003, 2013, and 2023 conducted using remote sensing techniques:

- The overall area of the basin's scrubland has decreased by 89.59% between 2003 and 2023. Following this, there has been a rise in the proportion of agricultural land that is in crops (36.33%), agriculture that is in fallow (53.553%), built-up areas (121.64%), and waterbodies (115.59%).
- Considering the internal conversion of different classes, the Upper Godavari River basin had a general shift from scrubland to waterbodies, crops, and fallow lands between 2003 and 2023.

This suggests that within a given period, the total amount of scrubland has decreased in lieu of an increase in other land cover elements like croplands and waterbodies in the span of 3 decades.

The following observations have been made along with the detection of LULC changes:

- From the data gathered, 19.9% increase in the river discharge has been observed in the years 2003 and 2013.
- In the years, a decrease in the ground water levels of Upper Godavari River basin has also been detected. The observed ground water level in the year 2003 was 8.59m which decreased to 7.01m in 2013 and further reduction to 6.69m in the year 2023. This implies a 4.67% fall in the ground water level throughout the years.

The study's findings demonstrate that, in the Upper Godavari

River basin, landuse has a significant impact on the streamflow discharge and basin hydrology changes. It was discovered that the SWAT model was helpful in determining how changes in landuse will affect the hydrological characteristics that are directly related to the watershed. For the Upper Godavari River Basin, a decrease in discharge was noted for the LULC change between 2003 and 2013 & between 2013 and 2023. The methodology employed in this study calculates the contribution of LULC changes on discharge, ground water levels, and surface runoff. This information helps decision-makers choose better options for land and water resources.

REFERENCES

1. Amin, A.; Fazal, S. Quantification of Land Transformation using Remote sensing and GIS Techniques. Am. J. Geogr. Inf. Syst.1, 17–28,2012. http://article.sapub.org/10.5923.j.ajgis.20120102.01.html
2. Anil, Z.C.; Katyar, S.K. Impact analysis of open cast coal mines on land use/land cover using remote sensing and GIS technique: A case study. Int. J. Eng. Sci. Technol. 2, 7171–7176, 2010. https://www.researchgate.net/publication/50384275_IMPACT_ANALYSIS_OF_OPEN_CAST_COAL_MINES_ON_LAND_USE_LAND_COVER_USING_REMOTE_SENSING_AND_GIS_TECHNIQUE_A_CASE_STUDY
3. Golaleh Ghaffari, Saskia Keesstra, Jamal Ghodousi and Hassan Ahmadi "SWAT- simulated hydrological impact of land-use change in the Zanjanrood Basin, Northwest Iran",Hydrological Process, 24, 892-903, (2010). https://onlinelibrary.wiley.com/doi/abs/10.1002/hyp.7530
4. Gautam, N.C.; Narayanan, L.R.A. Landsat MSS data for land use/land cover inventory and mapping: A case study of Andhra Pradesh. J. Indian Soc. Remote Sens.,11, 15–28, 1983. https://www.scirp.org/reference/referencespapers?referenceid=1911940
5. Kamal, P.; Kumar, M.; Rawat, J.S. Application of Remote Sensing and GIS in Land Use and Land Cover Change Detection: A Case study of Gagas Watershed, Kumaun Lesser Himalaya, India. Quest ,6, 342–345, 2012. https://www.researchgate.net/publication/271354076_Application_of_Remote_Sensing_and_GIS_in_Land_Use_and_Land_Cover_Change_Detection_A_Case_study_of_Gagas_Watershed_Kumaun_Lesser_Himalaya_India
6. R.K. Sinha, T. I. Eldho, S. Ghosh, "Investigation on Land Use/ Land Cover Change and Climate Variability on Runoff Generation – A Case Study of Valapattanam River Basin, India", IAHR World Congress, (3 July 2015). https://www.iahr.org/library/infor?pid=7808
7. Rawat, J.S.; Biswas, V.; Kumar, M. Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, Nainital district, Uttarakhand, India. Egypt. J. Remote Sens. Space Sci. 16, 111–117, 2013. https://www.researchgate.net/publication/259143603_Changes_in_land_usecover_using_geospatial_techniques_A_case_study_of_Ramnagar_town_area_district_Nainital_Uttarakhand_India
8. Rawat, J.S.; Kumar, M. Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. Egypt. J. Remote Sens. Space Sci.,18, 77–84, 2015. https://www.sciencedirect.com/science/article/pii/S1110982315000034
9. Roy, P.S.; Roy, A. Land use and land cover change in India: A remote sensing & GIS perspective. J. Indian Inst. Sci. 90, 489–502, 2010. https://www.researchgate.net/publication/235987981_Land_Use_and_Land_Cover_Change_A_Remote_Sensing_GIS_Perspective
10. Similes G. Setegn, Raghavan Srinivasan and Bijan Dargahi, "Hydrological Modelling in the Lake Tana Basin, Ethiopia Using SWAT Model", The Open hydrological Journel, 2, 49-62, (May 16, 2008). https://benthamopen.com/ABSTRACT/TOHYDJ-2-49
11. Sharma, K.R.; Jain, S.C.; Garg, R.K. Monitoring land use and land cover changes using Landsat imager. J. Indian Soc. Remote Sens. 12, 115–121, 1984. http://www.ecoeet.com/Monitoring-Land-Use-and-Land-Cover-Change-Using-Remote-Sensing-Techniques-and-the,154937,0,2.html
12. V. K. Dadhwal, S.P. Aggarwal and Nidhi Mishra, "Hydrological Simulation Of Mahanadi River Basin And Impact Of Land Use/ Land Cover Change On Surface Runoff Using A Macro Scale Hydrological Model," ISPRS TC VII Symposium, IAPRS Vol, XXXVIII, Part 7B, (5 July 2010). https://studylib.net/doc/11840314/hydrological-simulation-of-mahanadi-river-basin-and-impac...